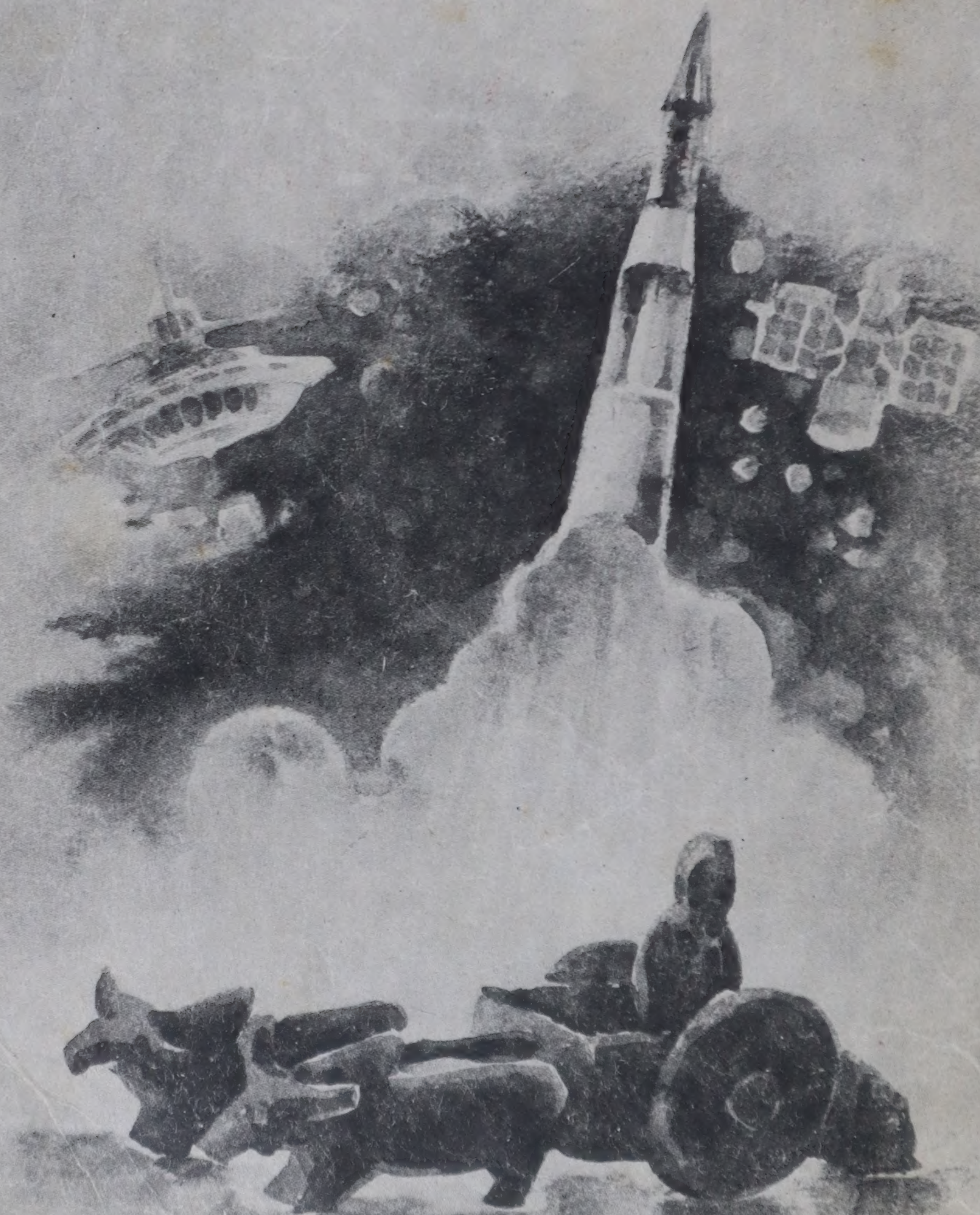


BULLOCK-CARTS AND SATELLITES

**THE DEVELOPMENT OF SCIENCE AND
TECHNOLOGY IN INDIA**

Monisha Bobb





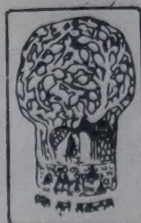
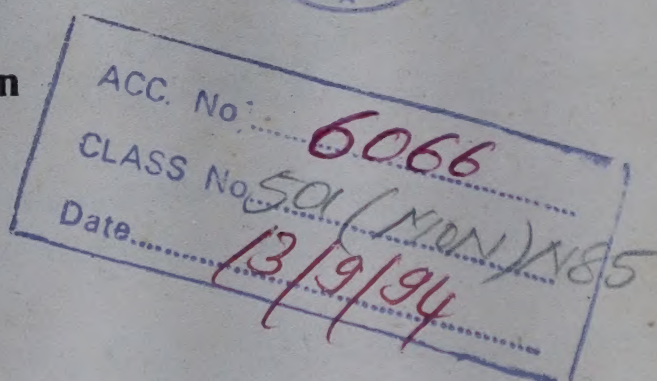
Nehru Bal Pustakalaya

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Cartoons by
R.K. Laxman



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1

When you watch the national programme on television each evening, you are looking at pictures which have been bounced off a satellite: a satellite made to India's specifications, the INSAT-IB, and maintained by Indian scientists. As you watch, you may be eating or drinking out of stainless steel vessels. That steel has been made in India. Perhaps you are wearing terycot clothes. The man-made terylene in your garments is made in Indian factories. Even the electronic watch you may wear is locally made.

In school, when you use computers, you are likely to be using Indian computers. Every bit of those computers, including the electronic semiconductor chips inside them, is Indian.

Today, none of this seems surprising. And yet, forty-four years ago, when India gained independence, our grandparents could not have dreamed of such a situation. In 1947, we had hardly any industry. We did not even make our own fountain pens. We had little technological expertise and we depended on other countries for most of our basic needs. Today, we make our own television sets and nuclear power stations. We make our own synthetic garments. We export high quality goods and technical expertise to countries all over the world. We have a team of scientists on the southern continent of Antarctica with other major countries of the world.

How did this happen? How did a country that was so backward in 1947 gather enough scientific knowledge and skill to develop so much so quickly?

It didn't happen all at once. It came as part of a logical development that goes back thousands of years into the distant past—five thousand years ago, in fact.

At a time when Europe was still inhabited by wandering tribes, a sophisticated, cosmopolitan society flourished in several well-planned towns in the valley of the Indus river. One of these towns was Mohenjodaro.

The people of Mohenjodaro built a city that would be a credit to any modern town planner. Straight, wide streets ran from north to south and from east to west, crossing each other at regular intervals, dividing the town into clearly demarcated blocks. The main streets were sometimes as wide as 30 feet and were lined with double-storied houses built of kiln-baked bricks of a standard size. Bathrooms were connected to properly laid out drains. A consciousness of sanitation and hygiene are evident from the fact that sewage was carried away in covered drains lined with bricks. 'Manhole covers', also made of brick, provided a means of cleaning the drains from time to time. Most of the larger houses in the city had their own well besides those for the general public so that a constant supply of water was available.

The inhabitants of Mohenjodaro were farmers and traders, craftsmen and labourers. The craftsmen produced well-made pottery which they decorated with floral and geometrical designs. Sometimes they drew birds and animals as well. They used clay and terracotta to make small figures of men and animals such as the elephant, the rhinoceros, the bull and the crocodile. The ingenious toys they made for their children included carts with wheels that moved—evidently models of similar wheeled carts that were in use at the time.

Sculpture in bronze was also well known and it is obvious that they knew a great deal about working with metal. Archaeologists have found bronze mirrors, needles, knives and razors, and ornaments for men and women made of gold, silver and copper. Rings, necklaces, bangles and headdresses were some of the ornaments that the people of Mohenjodaro wore. Apart from jewellery and sculpted figures, they used metal to make kitchen utensils. These were also made of pottery and stone. Baked pottery was the most commonly used material for utensils and dishes. Craftsmen were particularly skilled at making beads of gold and silver, faience and semi-precious stones. The quality of these beads is a reflection of highly developed processes that they had mastered.

The people of Mohenjodaro wore garments of cotton and wool which they evidently wove themselves.

Mohenjodaro and Harappa, Kalibangan, Lothal and Surkotada are some of the cities that comprised what is called the Indus Valley Civilization. Other settlements dating from this period existed beyond the valley itself, in places



such as Alamgirpur in Uttar Pradesh and Rupar in the Punjab. Excavations are still continuing at some of these sites, but from the material that has been discovered so far, historians and archaeologists have been able to reconstruct a fairly clear picture of the life of the people. Much has still to be understood, but certain facts stand out clearly.

The people of the Indus Valley Civilization knew a great deal about mathematics since they were able to plan well-proportioned cities with definite architectural features. They used the plumb-line in order to build double-storied structures. Their cities not only reveal an advanced standard of technical and engineering knowledge but their drainage system shows a strict enforcing of sanitation regulations. They had a sophisticated system of weights and measures and even the bricks with which they built their city were of a uniform size, a fact that indicates a high degree of standardization in production. They cultivated the land and knew how to make the alloys of various metals. They were prosperous and lived under a well-organized municipal system.

So much we know. There is undoubtedly a great deal that is yet to be discovered. The people of the Indus Valley Civilization were literate as well as artistic but historians have not yet been able to decipher their script. When this is done we will have more knowledge about this highly developed civilization, one of the earliest known to mankind.

Indus Valley pottery and beads





2

The Indus Valley Civilization appears to have ended comparatively suddenly. Around the time that it came to an end, there was a wave of migrants from the north—a group of tribes called the Aryans, who then settled in India. The Aryans established a new civilization with its own social, cultural and scientific customs distinct from what had existed before. This period is commonly called the Vedic period from the fact that most of our information about it comes from a group of hymns called the Vedas. From the Vedas and from other literature of this time, it is clear that the people had a culture which was fairly advanced.

The Vedic Indians studied astronomy. They were able to tell the time using the movements of the moon and the sun. They had names for the 27 positions of the moon and they knew how to work out the position of the new moon and the full moon.

Apart from using complex mathematics for astronomical calculations, the Vedic people used arithmetic and geometry to build altars and sacrificial places to very precise specifications, systematically using right-angled triangles. They also studied the properties of squares, rectangles and circles and knew how to construct them to particular proportions. They set down formulae on problems such as calculating the diagonal of a square and the squaring of a circle.

They evolved an atomic theory which stated that atoms combined together to form molecules.

Another sphere of development at this time was in the field of medicine. In order to study the human body in detail Vedic physicians practised dissection. Vedic treatises mention methods for dissecting corpses.

The sophistication of medical practice of the time can be attributed to the constant need for treatment of those wounded in battle in the frequent skirmishes and warfare that occurred between the invading Aryans and the local people and later, between the small kingdoms that came into existence. In fact, the art was known as *salyatantra*, the science of manoeuvring broken parts of arrows and other sharp weapons. Arrowheads that had entered the body needed to be removed, wounds inflicted by sharp weapons had to be tended and so knowledge and skill in dealing with such injuries grew. Surgeons were also in demand to repair noses, ears and other parts of the body which were often cut off in punishment in accordance with the brutal laws of the time. Bone-setting was also a highly skilled science in those days.

A great deal was known about herbs and their healing qualities. The treatment for leprosy which is used today dates back to Vedic times. In medicine, there was emphasis on the correct diet and doctors knew of the nervous system and the importance of the spinal cord.

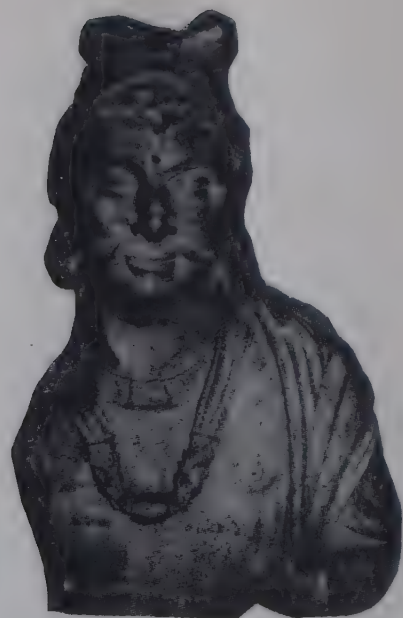
The Vedic people knew how to weave and dye the cloth which they wore. They used a variety of ornaments made of gold and silver, and were familiar with other metals as well. They enjoyed food and knew how to make an intoxicating drink called soma. They used several musical instruments and





their pastimes included chariot racing and dicing. Education and literature developed considerably and social customs became firmly established. In fact, many of the social and religious rituals that came into being during this period are still prevalent. Philosophy and religion form a major part of the Vedas and the subtlety of the thoughts and ideas expressed in them reveal a complex and sophisticated civilization.





3

The rule of the great Maurya dynasty, in the centuries just before the beginning of the Christian era saw a flowering of statecraft, culture, trade, and science.

We have detailed information about the period in the *Arthashastra*, a treatise written by Kautilya, who was the chief minister in the court of Chandragupta Maurya, who conquered vast territories and established the dynasty that bears his name. His descendants enlarged the kingdom until it encompassed a major portion of India and Afghanistan to form a powerful empire. Kautilya helped them set up a form of government that would hold the empire together. He was a master of the art of politics. The highly centralized system that he created was the first imperial government machinery in India and one of the earliest in the world.

Kautilya's *Arthashastra* gives detailed information on the way the Mauryan government functioned. But that is not all. He writes of other activities of the time, mentioning social customs, warfare, agriculture, and commerce.

He mentions several devices that were used in warfare, specially mechanical ones called *yantras*. These refer to simple catapults and incendiary devices since the use of gunpowder had not yet come to India.

It is clear from Kautilya's writings that agriculture had developed to the point of employing artificial irrigation. Canals and reservoirs are mentioned, which must have needed great engineering skill to construct.

Among useful gadgets of daily use was a revolving water spray to cool the air during the summer.

There was, at this time, a great deal of interest in the development of the



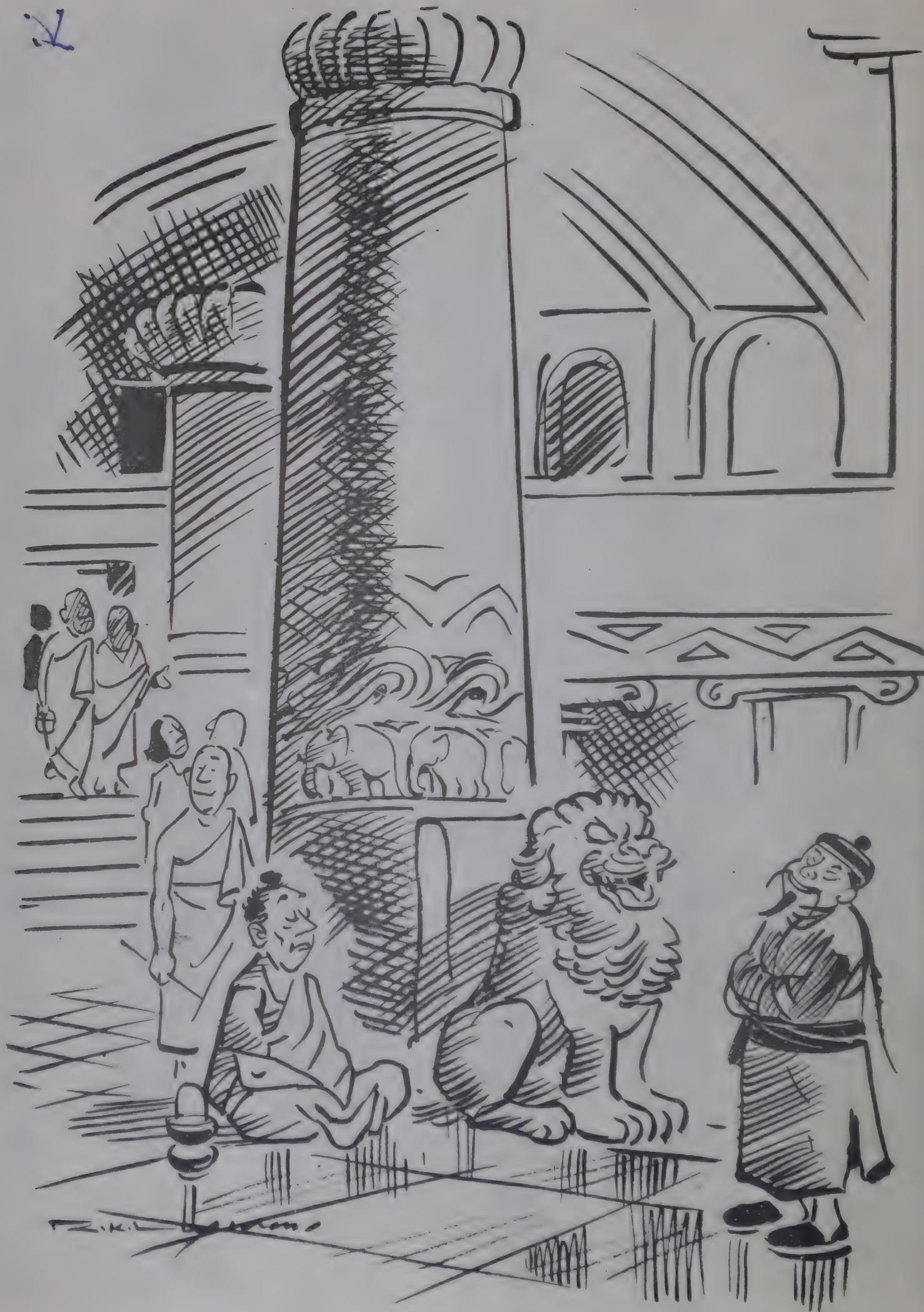
sciences of phonetics and grammar. The important contribution in this field is undoubtedly Panini's great Sanskrit grammar. After Panini, Sanskrit as a language did not change radically, although its vocabulary and literature continued to grow. Panini's work is a remarkable achievement and it has generally been recognized that such a detailed scientific grammar was unparalleled anywhere in the world until the nineteenth century.

The greatest of the Mauryan kings, Ashoka, began his reign by leading his armies in a series of wars of conquest in the traditional manner. However, he later became a Buddhist, turned his back on war and worked for the welfare of his people with a paternal benevolence which was remarkable for a ruler of the time. He constructed roads across the length and breadth of his empire, so that his capital at Pataliputra was easily accessible to every part of his dominion. The technical know-how necessary to survey the land and build these roads was

← Ashokan pillar—a marvel of non-corrosive metallurgy

↓ Stupa at Sanchi





obviously of a high level. Ashoka also set up shady wayside resting places for travellers and established hospitals and refuges for men and animals. Under his patronage medical knowledge grew, as did the study and care of animals.

Little remains of Ashoka's capital at Pataliputra. There are hardly any ruins to tell us about the architecture and town planning of the Mauryan builders. However, Greek historians and travellers have mentioned the splendour of the Mauryan capital and refer to the fact that the palaces and buildings were made

The Ashokan column at Sarnath



of wood. Ashoka's palace is supposed to have been so impressive that the Chinese traveller Fa-Hien believed it was built by spirits in the service of Ashoka. The carvings which surmount the Ashokan pillars make it clear that skilled craftsmen who knew a great deal about working with stone were very much part of the Mauryan scene. Each of these pillars has been made from a single block of hard stone, polished to perfection and engraved with Ashoka's edicts. A good deal of engineering expertise is evident in cutting these huge blocks and transporting them hundreds of miles from the quarry, sometimes to the top of a hill. They have withstood the ravages of time and can be seen in Delhi and in other places in India.

It was during this period that several stupas were built, to enshrine the relics of the Buddha. The most famous of these are at Bharhut and Sanchi.

As Buddhist monks began to be more organized, they set up monasteries to live in. They sought suitable locations and cut caves out of rocky hills in such places as the Barabar hills. Some of these caves were later decorated with carvings by the monks.

A few centuries later, shortly before and after the birth of Christ, workers in stone began to excavate and sculpt caves at what we know as Ajanta, Karle, Nasik and Bhaja in western India. In the east, similar activity was in progress in Udaigiri and Khandagiri. Work on the stupa at Sanchi continued and during this period, the stupa was enlarged and its original wooden railing was replaced by one of sculptured stonework.

Although our knowledge of Mauryan art and architecture is fragmentary at best, there is enough information to conclude that Mauryan art and the technology reflected in it had reached an advanced stage.





4

During the centuries that followed, astronomy, mathematics and medicine continued to progress; new discoveries were made, new methods developed.

The names of two famous physicians have travelled through the centuries in texts which have preserved fragments of their teachings. Caraka wrote the *Carakasamhita*, a work that is considered the basis of the Ayurvedic system of medicine. Ayurveda, which means 'the science of life', is still practised in India. Caraka seems to have known that the heart is the controlling organ in the body. He also knew something about the circulation of blood. He was aware that certain diseases are caused by germs, some of which he said were invisible to the naked eye. Caraka's work mentions the existence of hospitals and trained medical practitioners. It is evident from his writings that ancient Indian physicians and surgeons knew a great deal about the human body and the treatment of disease.

This view is reinforced by what we read of the art of surgery that existed at the time in the work of Susruta. Susruta's treatise, the *Susrutasamhita*, is held to be an outstanding contribution to medical literature.

Susruta evidently collected all that was known about surgery and put it down systematically. In his work, he recommended that students acquire skill by dissecting dead bodies and outlined a method by which the body should be prepared for dissection. Susruta also listed the instruments that a surgeon should have and suggested that each practitioner devise new instruments to suit his own particular needs, in addition to those which were already in use. Among the instruments he listed were forceps, knives, needles, probes and

tubular instruments all of which a modern surgeon uses, though in a more refined form. Apart from dissection, Susruta suggested that apprentices practise on a variety of objects such as vegetables and leather bags filled with mud. He advised students to attain proficiency not only in surgery but also in areas such as the stitching of wounds and in bandaging.

Susruta was also knowledgeable about plastic surgery. Here again, injuries received in battle, particularly to the ear and nose, were dealt with in a systematic way. Susruta laid down methods of dealing with damaged noses that are relevant to plastic surgery as it is practised today.

The decline and end of the Mauryan empire was followed by a period of confusion, when several small kingdoms took the place of a single imperial state. Then there arose another line of empire builders and they established what is called the Gupta dynasty.

During the Gupta period, traders carried Indian goods to distant countries. The demand for Indian goods expanded and so did trade and commerce. Prosperity followed this growth and soon, wealthy individuals and institutions were patronizing scholars and artists. A large number of scientific treatises were written at this time and scholars collated the information available to them, classifying contemporary knowledge skilfully and systematically.

Indian art and culture spread to neighbouring countries and so did Indian scientific knowledge. Knowledge from other parts of the world also found its way back to India and acted as a stimulus to further thought.

This period saw the birth of several mathematicians of genius, the most important of whom was Aryabhata, in whose memory the first Indian satellite was named. Aryabhata lived around the fifth century A.D. His work in algebraic formulae is quite remarkable. He gave the value of π as $3 \frac{17}{1250}$ or 3.1416, which is very close to the value assigned it today. He also wrote on other branches of mathematics. He laid down rules for determining square roots and cube roots, areas and volume. He understood the concept of sines. In the field of astronomy, he described methods by which to calculate the position of planets and knew the reason for the eclipses of the sun and the moon and could forecast them accurately. He had discovered that the earth rotates on its axis and it and other planets move around the sun. In the West, this was not known until almost a thousand years later.

Other astronomer-mathematicians who made important contributions to the knowledge of this period were Latadeva, Varahamihira and Brahmagupta. All these mathematicians had analytical minds and a complete understanding of numbers. Their contributions to algebra, geometry and arithmetic are outstanding.

18. According to us



Susruta as an artist's impression

Indian mathematicians were the first in history to use the concept of an empty space, called *sunya*, which later developed into the zero, now a vital part of mathematics. In fact, even the English numerals used today, which are commonly called Arabic numerals, actually originated in India. They were used in the edicts of Emperor Ashoka, centuries before there is any record of the Arabs having known of them. These numerals and the decimal system were carried by Arab traders from India to the rest of the world. Aryabhatta and Brahmagupta were both using the decimal system long before the Chinese or the Arabs were familiar with it. These are among India's great gifts to the world in the field of practical knowledge.



Gupta coins

One of the major sources of information about the kings of the Gupta empire are the coins they minted. These beautiful gold coins are evidence of a high technical skill. Metallurgists also used their mastery to produce objects of copper and iron which are so well finished that they have withstood the wear of centuries and can still be seen in museums today.

Ajanta Caves →



The iron pillar at Mehrauli in Delhi which has still not rusted despite being over two thousand years old; the 80-foot copper image of the Buddha at Nalanda; and the 7½ foot Sultangunj Buddha statue in copper are some notable examples of the expertise of the metallurgists of ancient India.

At the time there was also an expansion in the mining industry. Records mention the mining of gold, silver, copper, lead, tin and iron, which were made into ornaments and more useful objects, such as vessels, implements and, of course, all the paraphernalia of warfare.

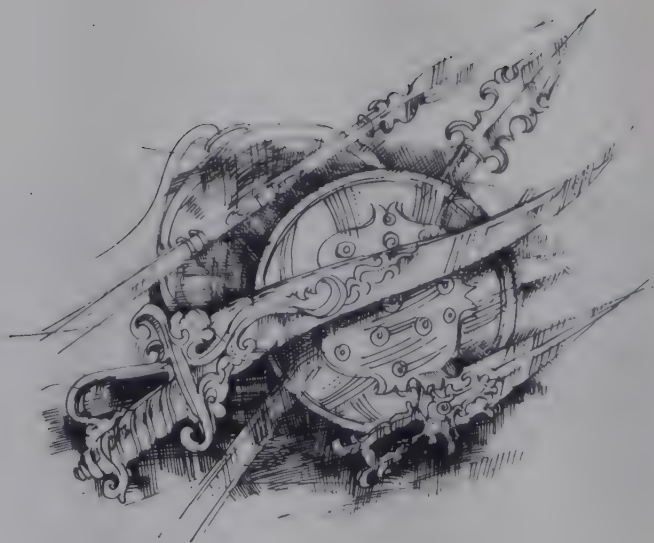
The artisans who made these and other goods, such as wood and ivory carvings, paintings, pots, fabrics and so on, were organized into guilds and the members of a particular guild lived together in a separate part of town.

The guild system did not come into existence in Europe until the Middle Ages. In India, it was an established way of life at the start of the Christian era.

Much of this social and economic organization was to remain unchanged in the ensuing centuries of upheaval. Forms had been set and traditions established and those that followed built upon these bases.

Iron pillar near the Qutb Minar, Delhi





5

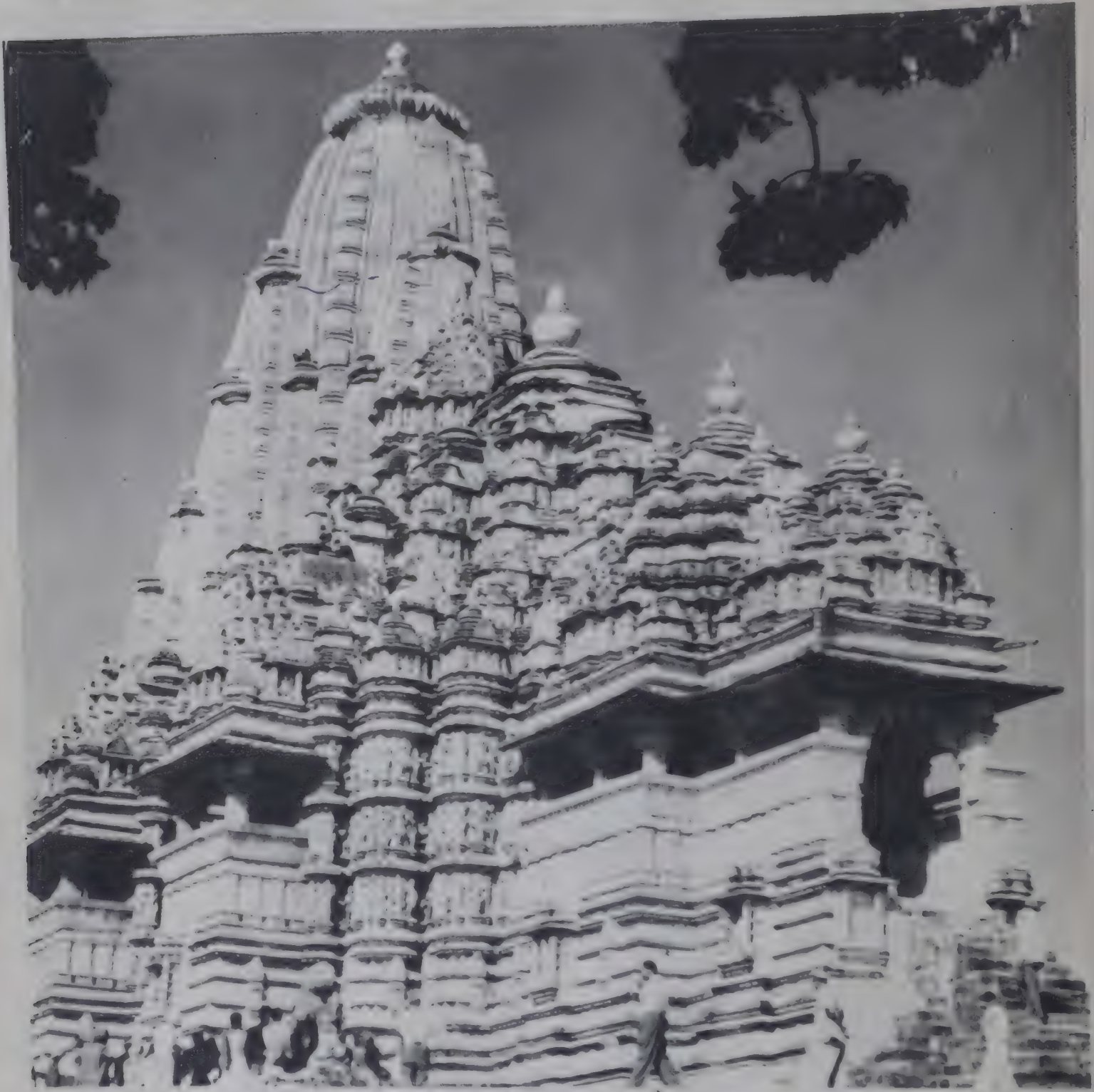
In the years after the decline of the Gupta empire, there were many small kingdoms warring for pre-eminence. The period is marked by little advance in most spheres apart from religion and architecture which saw a flowering in the temples found at Khajuraho, Bhubaneswar, Kanchipuram and Thanjavur. The start of the tenth century brought a wave of invasions. Turkish armies marched into the Gangetic valley and eventually established their domination over the whole of north India.

The rulers of the period called the Sultanate were too involved in conquest and warfare to make many changes in local traditions. Ancient ways of manufacture and trade continued and grew, especially in those products that were valued by the new rulers. Industries such as textiles, continued to produce fine cotton, silk and wool. Carpets, mats, gold and silver embroidery, quilts and mattresses and all the luxuries of an affluent and vigorous society were produced in great quantity. The mining industry flourished and gold, silver, lead, iron, copper, diamonds and sulphur were mined on a large scale.

Metal workers were kept busy and skilled artisans made objects of good quality iron and steel. Swords, matchlocks, armour, guns and cannon-balls were all produced and so were less destructive objects such as farming implements and household utensils. Iron beams were used in construction and in the building of seaworthy ships.

As the Sultanate in India became firmly entrenched, and peace was restored, scholarship revived and flourished, particularly in the fields of medicine, astronomy and mathematics.

Historians of the time mention many famous surgeons and physicians. Some classified the knowledge at their disposal and several treatises were compiled. Muhammad-bin-Tughlaq, during his reign in the fourteenth century,



Khajuraho temple

ordered not only a compendium of medical knowledge but also a collection of veterinary information. This was important because horses and elephants were the major means of transportation at that time.

Lingaraj temple, Bhubaneswar →



However, it was in the field of human surgery that the skill of medieval doctors seems to have been particularly amazing. They performed complicated operations and even made artificial limbs.

Astronomy and mathematics were also studied. The most celebrated name of this period is that of the astronomer-mathematician Bhaskara II. Bhaskara II's work in the field of indeterminate analysis was centuries ahead of similar discoveries in Europe. He also contributed to the development of the theory of numbers. He was equally knowledgeable in the fields of geometry, arithmetic and algebra and also developed formulae of astronomical interest, using sines of angles. Bhaskara II's outstanding work is *Lilavati*. It is divided into two parts,

Qutb Minar →

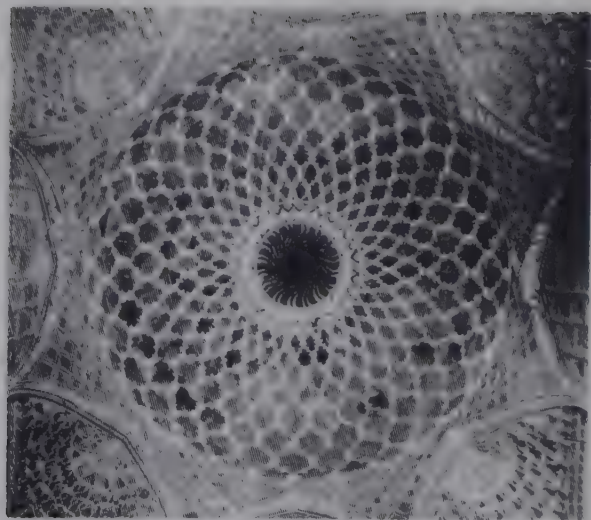




arithmetic and algebra and is written in verse. His manuscripts were translated into Persian and used by scholars in later times. Another famous mathematician was Narayana, who worked with magic squares.

The other field in which research was done was alchemy and Indian work in this science spread to various neighbouring countries.





6

With the coming of the Mughals, research and innovation in science and technology continued. In the field of geometry Mir Mohammad Hashim and Maulvi Muhammad Barkat wrote scholarly treatises.

The study of astronomy was considered particularly important for it was used to calculate the exact time and to forecast astrologically important occurrences such as eclipses. Observatories had been set up under the Sultans of Delhi and later under the Mughal emperors as well, but perhaps the most ambitious achievements were those of Sawai Jai Singh, the founder of the city of Jaipur. Sawai Jai Singh built a series of massive masonry instruments at observatories in Jaipur, Delhi, Mathura, Ujjain and Varanasi. He chose to build his instruments of masonry instead of using the more common metal instruments because he felt the latter were too small to provide adequately accurate readings.

Sawai Jai Singh's deep interest in establishing a precise means of reckoning the time led him to study the existing methods such as hour glasses and sundials and consult the calendars that were in use. He decided to tally the findings of these devices with the position of the stars and planets in the sky. In an effort to collect all the information he could, he had various works translated into Sanskrit and invited many scholars and astronomers to his court.

Sawai Jai Singh used his new-found knowledge to formulate tables of observations, which he included in a work on astronomy called the *Zij-i-Jadid-Muhammad Shahi*.

Other astronomers also made valuable studies in this field. One of these was

Mulla Farid Manajam, who prepared an astral chart during the reign of Shah Jahan.

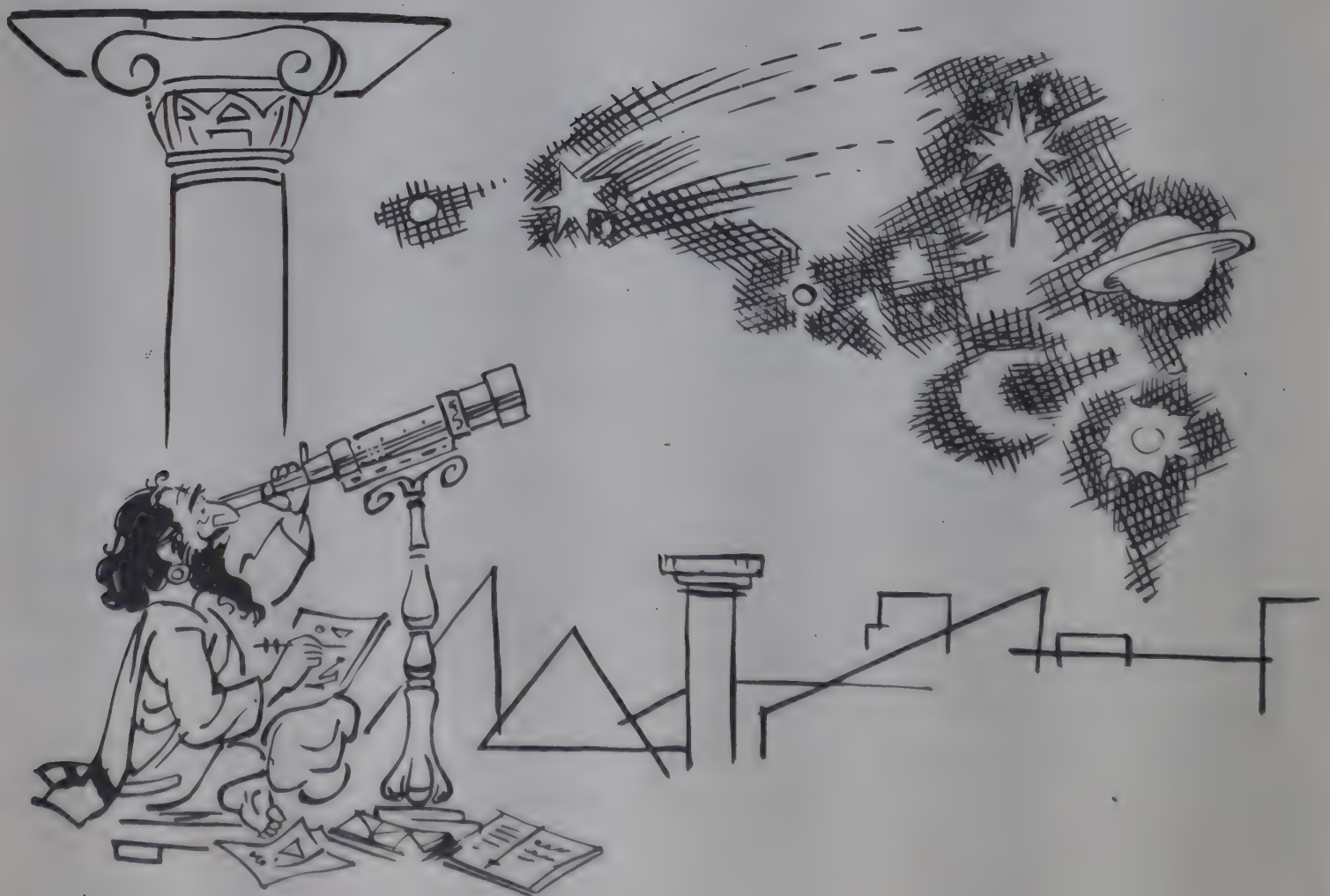
The use of tin to coat copper utensils became very popular during the Mughal period and for decorative articles the lead alloy *bidari* was used. Both white and coloured enamels were also developed.

The one metal which was not known in Europe till much later but was in common use in India was zinc.

Shipbuilding became an important industry during the later Mughal period, and ships sailed up and down the coast and across the ocean in pursuit of trade.

Medicine covered a vast range. Treatises which have come down to us from this period suggest detailed and specialized knowledge. Considering that animals were of vital importance as a means of transport and in wars, it is not surprising that medical scholars had over the years been turning their attention

Jai Singh's astronomical instruments—Jantar Mantar →



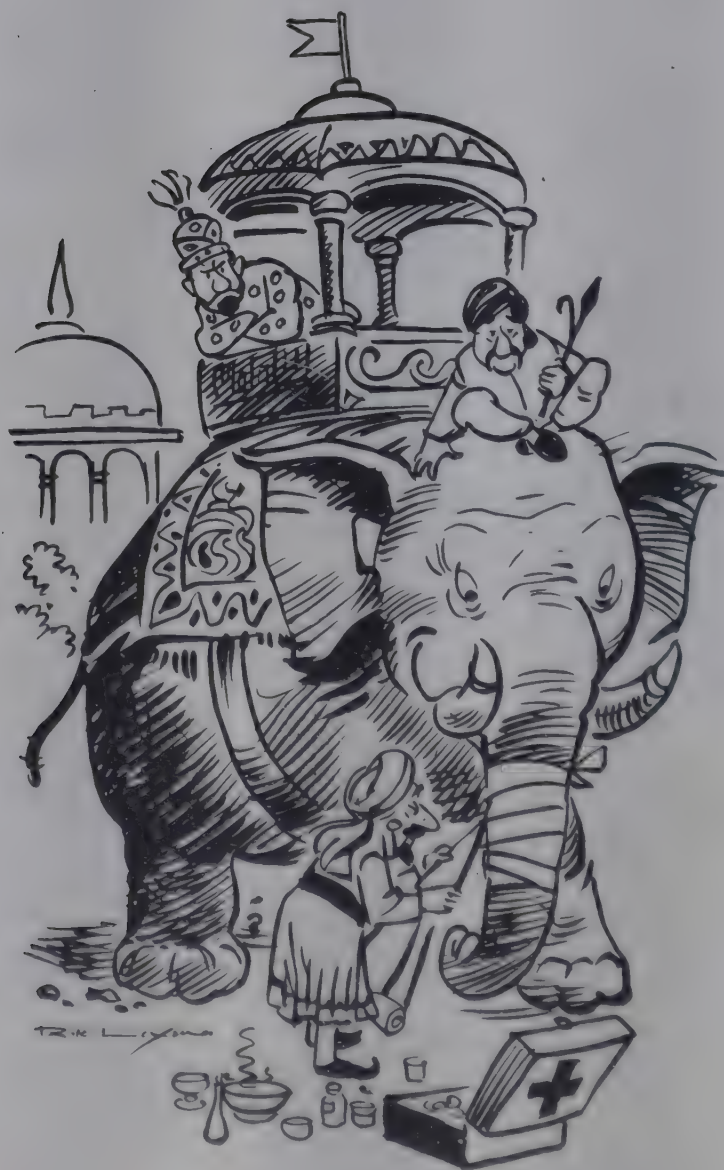


to dealing with their ailments. During Akbar's reign, there is even mention of a surgeon for elephants.

The emphasis given to diet is reflected in a number of works. Allied to this was the careful preparation of food preserves such as chutneys and of beverages such as sherbets. A great deal of classification of knowledge of medicinal plants and their uses also dates back to this period.

The Mughals were lavish patrons of the arts. Apart from the exquisite miniature paintings produced by court artists, architecture developed in original and extraordinarily beautiful forms. The dome and the arch took on a new look when Mughal architects combined them with traditional Indian ornamentation. The Mughal school of architecture used a mixture of Indian and Persian forms to produce a unique and very pleasing style. Among the marvellous

Taj Mahal →



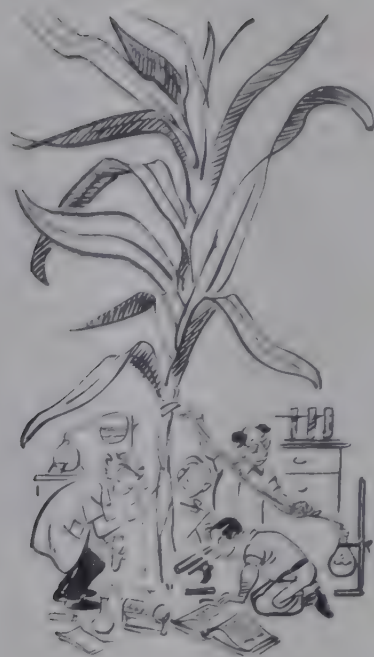


bathrooms in Mughal palaces were also constructed with great skill and were equipped to give the emperor hot or cold water as he desired.

Indian jewellery was renowned all over the world and the expertise of Indian goldsmiths reached a peak during the time of the Great Mughals who delighted in wearing a variety of ornaments on their persons.

Flora and fauna were subjects of interest during this period, and in the reign of Jehangir, in particular, court painters produced exquisitely detailed and knowledgeable pictures of animals, birds, flowers and other living things.





7

The classification of Indian plants, animals and birds continued after India came under British rule but scholarship in other fields suffered. With the end of the royal patronage of learning, there was a diminishing of original research and study. And yet, despite the fact that this period was so barren in scientific and technological terms, a few men of genius rose above their circumstances to make their contribution to scientific knowledge. Jagdish Chandra Bose overcame a crippling lack of equipment and resources to continue his work, which eventually produced short radio waves. His experiments with electro-magnetic waves predate those of Marconi. He also made a major contribution by observing the effects of sleep, food, air and drugs on plants and their growth and devised extremely sensitive apparatus for his experiments.

C.V. Raman was another scientist of genius and his work was on the properties of light, including an explanation of the colours of the sky and the sea. C.V. Raman's research earned him the Nobel Prize in 1930. S. Ramanujan was a brilliant mathematician whose research in the field of mathematical theory won him fame and admiration all over the world. Another outstanding scientist was the botanist and geologist Birbal Sahni. His field of specialization was palaeobotany, the study of fossil plants from which we gain knowledge of mineral wealth such as coal and petroleum.

These and other extraordinary men were, however, an exception to the norm. British interest in India was based on the needs of commerce and the requirements of maintaining British domination. Craftsmen were in great demand to produce goods for Western markets. Labourers were required to

build roads and railways which not only facilitated trade but also helped strengthen administrative control of far-flung areas of the empire. But jobs which required decision-making abilities or innovative thought went to Europeans. Money was invested in mills and factories which served British interests. Britain wanted to keep India as a supplier of raw material for its industries and a market for its manufactures so those areas of science and technology which furthered British industry were mainly developed.

In agriculture, research was focussed on particular crops which filled the requirements of British markets such as cotton, jute, sugarcane, tobacco, indigo, tea, coffee, coconut and oil-seeds.

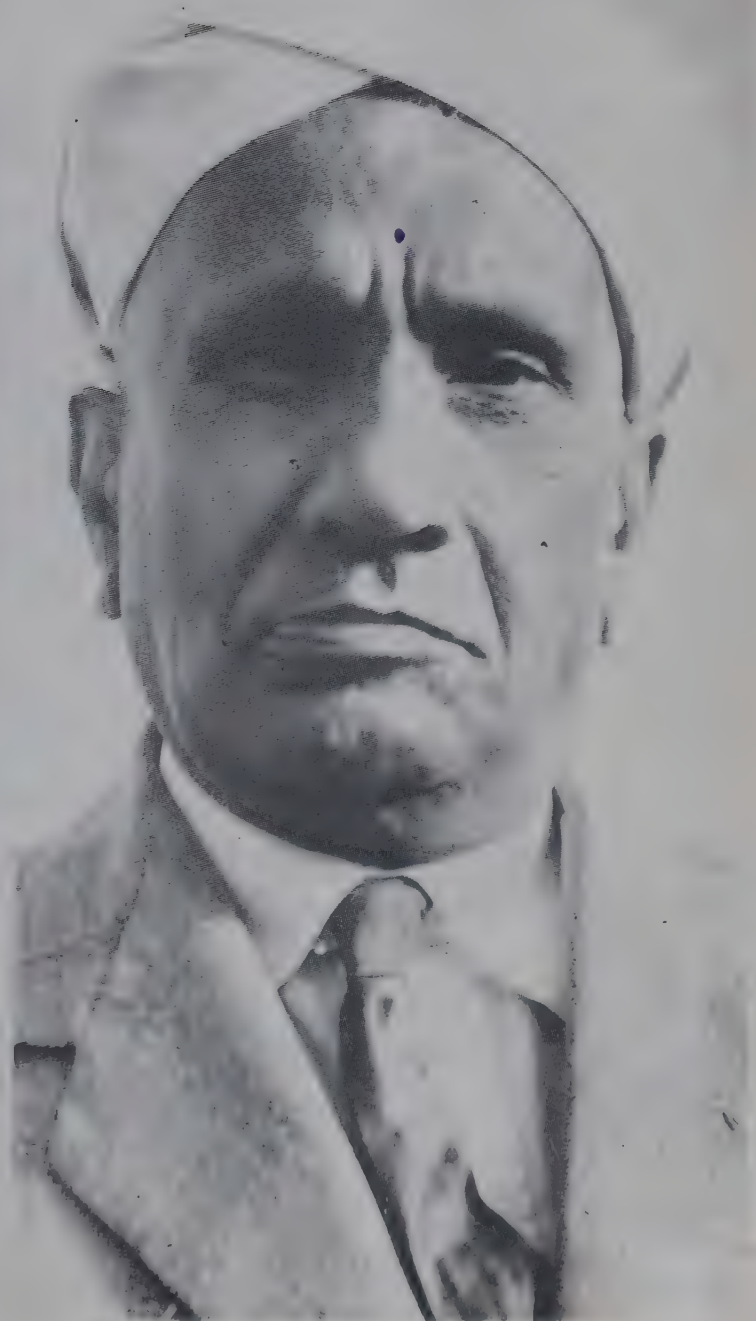
In the field of medicine as well emphasis was on finding the causes and cures for tropical diseases such as cholera, malaria and plague which took a heavy toll of British army and administrative personnel.

Very little money and encouragement was forthcoming for local research and scholarship. The work that was done on the classification of Indian resources, was done by British scholars who had the financial backing to enable them to devote their time to such work.





C.V. Raman



S.C. Bose

Thus, the technological advances that did take place, such as the modernization of the means of production, the establishment of factories and mills, tea and coffee estates, and a modern banking system, were geared to satisfy the practical needs of the British empire.

Notwithstanding this, important scientific and technological strides were made in the fields of engineering, agriculture, botany and medicine by the British in India. Pains-taking and often outstanding British scientists and technocrats left behind a legacy of dedication, objectivity, accuracy and in the last analysis a strong infrastructure which Indians were able to build upon and develop to suit the requirements of independent India.

my nady is a super star





When India became independent in 1947, it was economically dependent on the West. Indian mills produced vast quantities of cloth, and commodities such as Indian tea and coffee were in demand all over the world, but heavy machinery, vehicles and tinned foods all had to be imported. India was dependent on Western engineers and on Western architects and town planners. Its educational system had its roots in an alien environment. Its communications network and commerce were geared to benefit its previous rulers.

And so, when the government of independent India took over, it was faced with the task of reorganizing the entire economic structure of the country. Institutions to encourage scientific learning and innovate technological research that would be relevant to Indian needs and conditions were immediately set up. Indian men and women had to be educated in fields which would contribute to the development of the country.

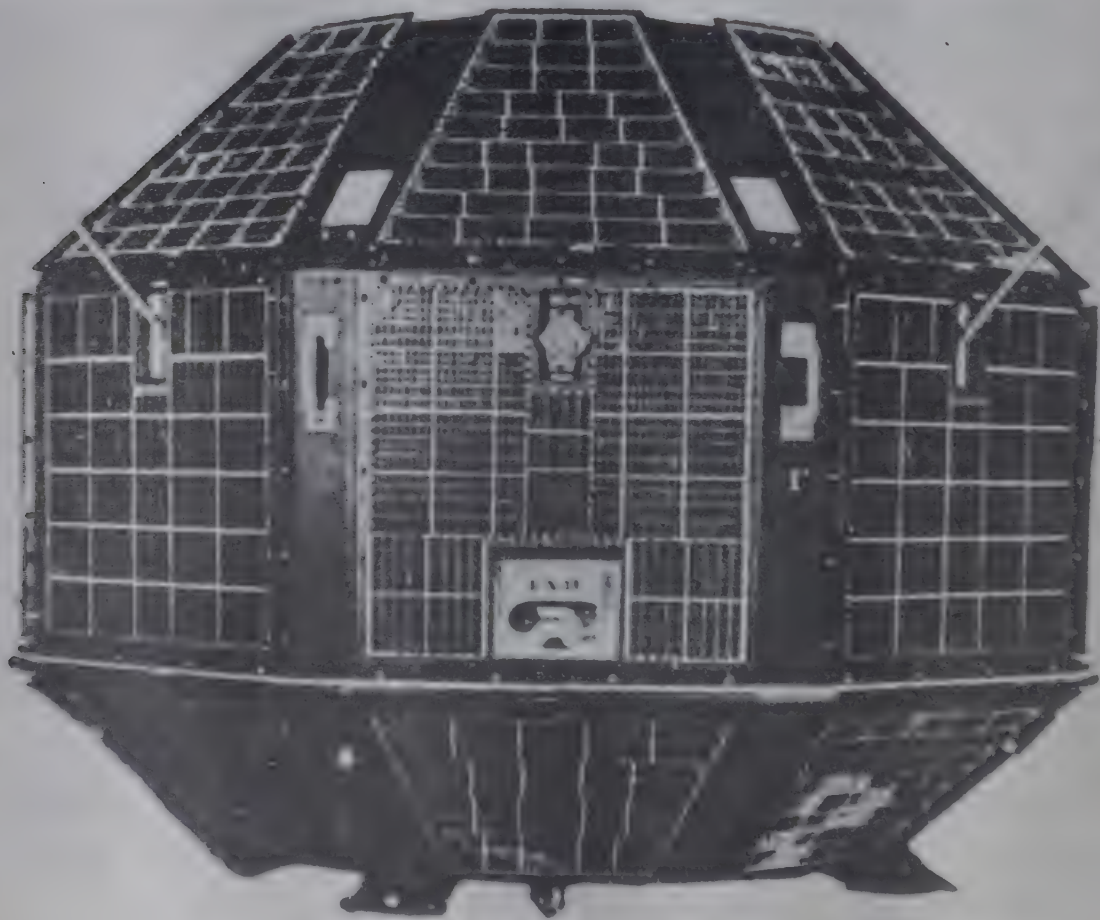
The emphasis on science and technology is evident from the fact that a Ministry of Science and Natural Resources was formed by the first government of independent India and the Prime Minister, Jawaharlal Nehru, decided to hold charge of the ministry himself.

This impetus, coupled with the already existing potential, has created within the short span of 44 years the third largest scientific and technical manpower in the world. It has transformed India from being largely a supplier of raw material into a major industrial economy.

India has made spectacular strides in a number of diverse areas. In a logical follow-up to past studies in astronomy, modern scientists are involved in space

research. India's interest in space is part of its programme of national development. Its research is aimed at improving mass communications via satellites, surveying national resources with the help of remote sensing devices and, of course, the study of space itself. The Indian Space Research Organization has four major establishments in Bangalore, Trivandrum, Sriharikota and Ahmedabad, at which research and experimentation are conducted. Among the achievements of the Indian space programme are the launching of a series of sounding rockets to gather information on the upper atmosphere and the fabrication of satellites. India's first satellite, launched in 1975, was appropriately named Aryabhata. India has since built 11 satellites, amongst them the IRS-1A, which is a remote sensing satellite. Since it was launched, two years ago, the IRS-1A has been providing photographic information from space. This information has been used for a variety of purposes. The INSAT-1B, which was made to Indian specifications by the USA, is an important communications satellite. It is used for long-distance telephone calls and for computer link-ups. And, most important of all, it is being used for nationwide television broadcasting. The national programme on television is broadcast with the help of

A Rohini rocket →



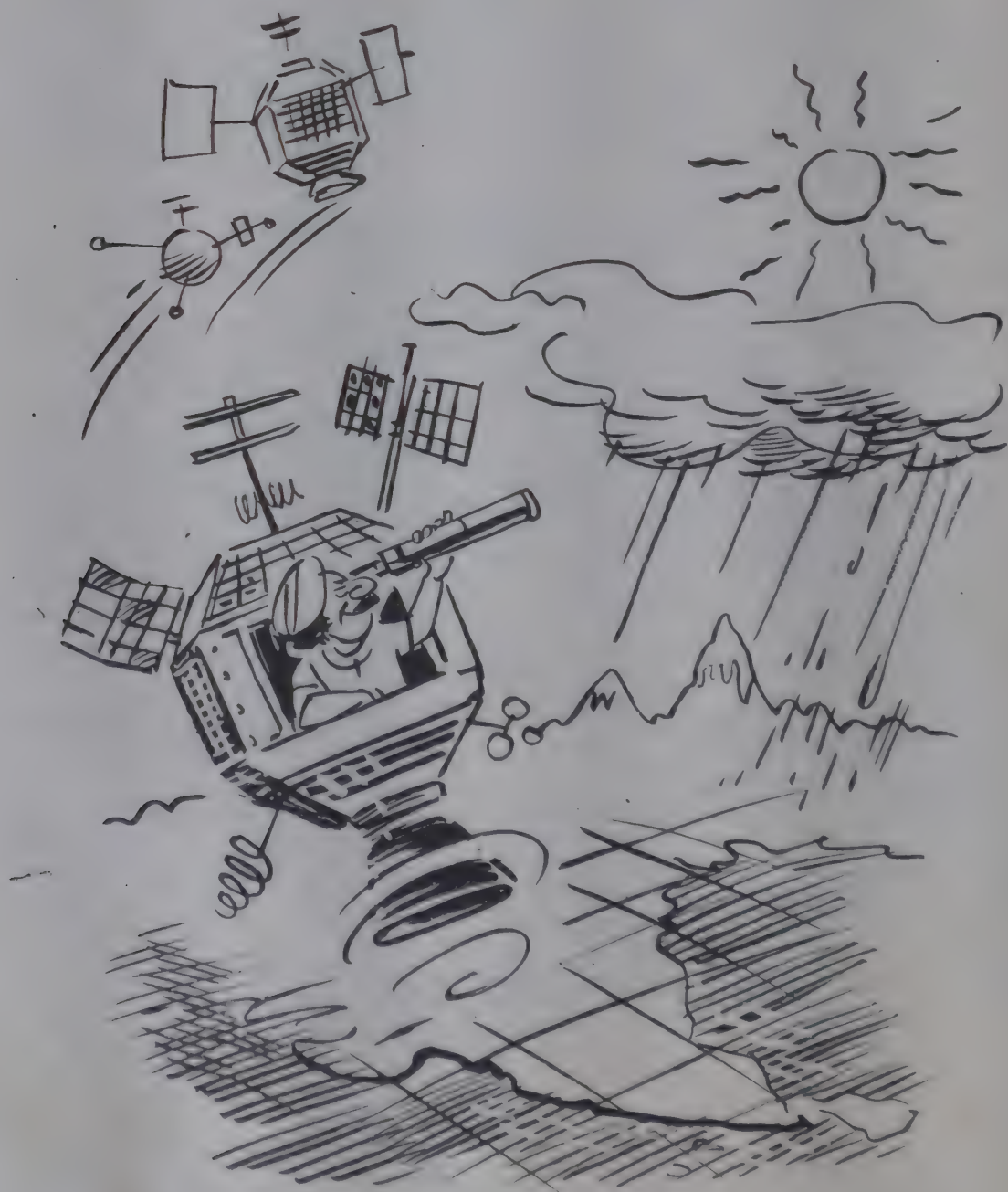
Aryabhata—India's first satellite



INSAT-1B. This satellite also provides important information on the weather. Other satellites have helped, and continue to help, scientists to gather valuable information related to meteorology, astronomy, geology, the ocean surface, agriculture, the ionosphere, remote sensing of various resources, communications and, of course, the study of space.

The Thumba Equatorial Rocket Launching Station, which is located close to the geomagnetic equator, in Kerala, is an internationally recognized base for the launching of sounding rockets to study the atmosphere. Scientists from all over the world have taken part in experiments which originated at Thumba.

In 1979, India participated in the monsoon experiment, commonly known as Monex, which was part of a world programme to study the atmosphere and



the weather. Some of the experiments involved collecting information by sending up rockets and receiving data from satellites.

With the rise in oil prices over the last decade, Indian scientists have stepped up their efforts to discover new sources of this valuable commodity. The Oil and Natural Gas Commission, the ONGC, is the government body which has been involved in oil exploration since 1956. Its efforts resulted in the tapping of new sources of both oil and gas, but perhaps its most dramatic achievement has been the setting up of massive floating platforms off the coast of Bombay to drill for oil under the sea. These oilfields in the Arabian Sea, commonly known as Bombay High, produce crude oil and gas which are carried to the shore in undersea pipelines.

India is interested in using nuclear power for peaceful purposes. The Tarapur Atomic Power Station started functioning in 1969. It was the first nuclear power station in India. Since then, several other nuclear power stations

Offshore oil platform



have been set up in various parts of the country in an effort to produce cheap power for industry and for domestic use. Nuclear research is carried out at the Bhabha Atomic Research Centre in Bombay where there are three research reactors. One of these is amongst the largest isotope-producing reactors in the world. Scientists are experimenting with the use of radioactive materials in other areas such as medicine and agriculture.

To support the nuclear programme, the government has established the Atomic Minerals Division. It is responsible for systematically surveying the land and discovering deposits of minerals which are likely to be useful to India's development.

As a leader among developing nations, India offers facilities for training and research to other countries trying to develop their technology in this area.

India's nuclear explosion in 1974 was another step towards harnessing this form of energy for peaceful purposes.

Closely connected to atomic and space research is the field of electronics. The Indian government has an Electronics Commission to foster and direct growth in the electronics industry. Apart from a number of government corporations producing electronic components and systems, there are also several private organizations. Both government and private corporations constantly introduce new ideas and processes in this highly sophisticated technological field. Electronics for the consumer market include components for televisions, calculators and watches.

Indian computers, made by Semiconductor Complex Ltd., are now being used by schools all over the country. In recent years, other computers have simplified the railways reservation system, banking systems and several other areas of daily life.

The PARAM family of computers, announced in 1990 by C-DAC, Centre for the Development of Advanced Computing, Pune, is a super-computer which is capable of parallel processing. In such a computer, a large and complex problem is broken up into small portions and all of them can be worked upon at the same time. This is useful in a variety of fields, from making cartoon films to spaceship design and weather prediction.

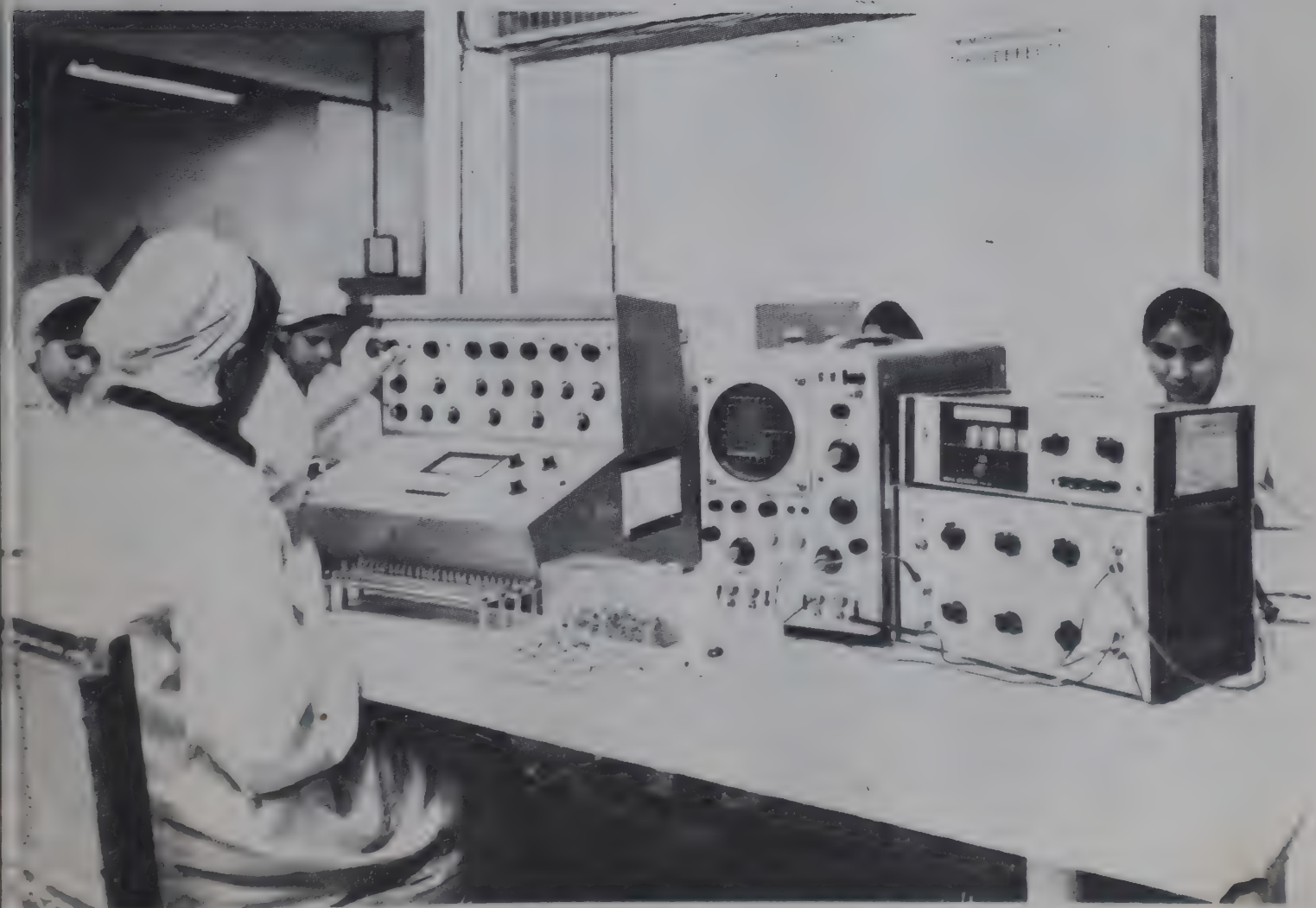
An area in which India has made rapid progress is that of high-tech telephone exchanges. C-Dot, the Centre for Development of Telematics, has created up-to-date automatic telephone exchanges and these are now being used all over the country.

As the search for new sources of energy continues throughout the world, Indian scientists are investigating the possibility of using solar energy to meet our needs. Other, simpler sources, such as bio-gas, wind energy and even the



India's first 16-bit computer

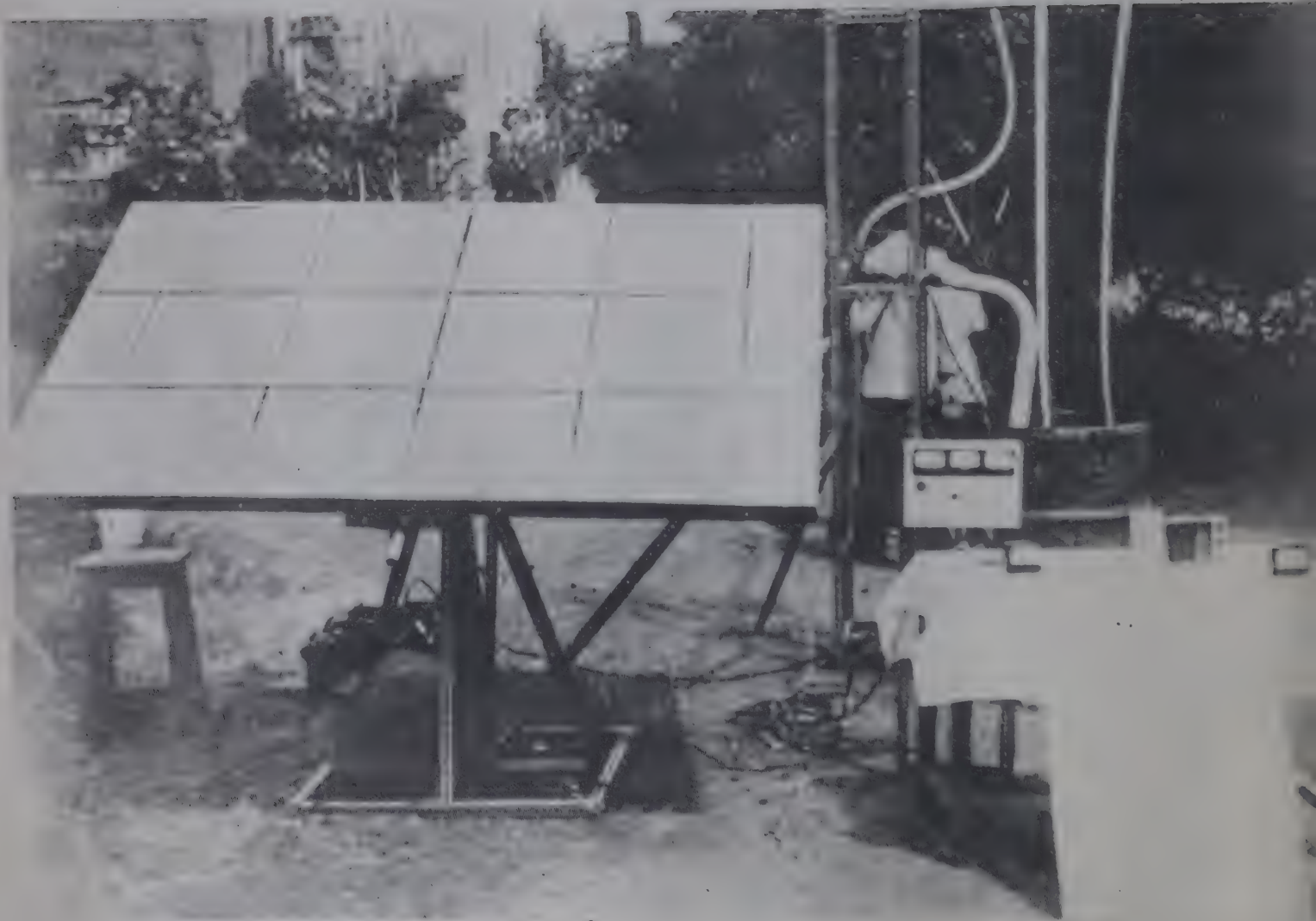
Electronic aid to quality assurance



energy from waves are being investigated. Bio-gas is being used to provide fuel in certain parts of the country.

In every area of our lives, new developments and new technologies are affecting the way we do things and the way we see our world. From a position of technological backwardness in 1947, India has rapidly become a leader among developing nations, even in the new sciences of space, atomic energy and electronics. It is always ready to share its knowledge and skill to help other nations, not only in these highly sophisticated fields but in other areas as well.

Indian-made solar pump





9

The people of the Indus Valley Civilization cultivated their land as far back as 2500 B.C. Since then, farming has been the basis of the Indian economy. Agriculture is no longer a simple matter of planting seeds and harvesting crops. It requires a great deal of technical knowledge and skill to use land productively. Indian scientists are studying new and improved methods to increase the yields of farmlands and to develop new strains of food grains. Enormous strides have been made in plant breeding, insecticides and fertilizers. New farming implements have been developed. Scientists have bred new strains of wheat and rice which mature quickly, have a higher yield, and can be harvested more frequently. Research in oil-seeds, vegetables and fruit, has already resulted in an improvement in the variety and yield of these crops. We have come a long way from the time of the Mughals, when fruit had to be transported from Afghanistan and was only for the royal table. Today, mounds of fresh fruit and vegetables are widely available.

Grain and fertilizers, farm implements and know-how would be of no use if fields could not be watered. There was a time, not so long ago, when Indian farmers were at the mercy of the monsoon. Anxious faces scanned the skies every year for the much-needed rains. The timely arrival of the monsoon is still vital, but erratic rainfall is now supplemented by a vast network of irrigation projects. Massive dams have been built all over the country and incredibly long canals carry water to once barren regions. An ambitious project is the Rajasthan canal, which is still under construction. A portion of the canal has already made a section of the desert bloom. The main canal is 280 miles long and, when it is

ready it will take life-giving water to large areas that are presently part of the Thar desert.

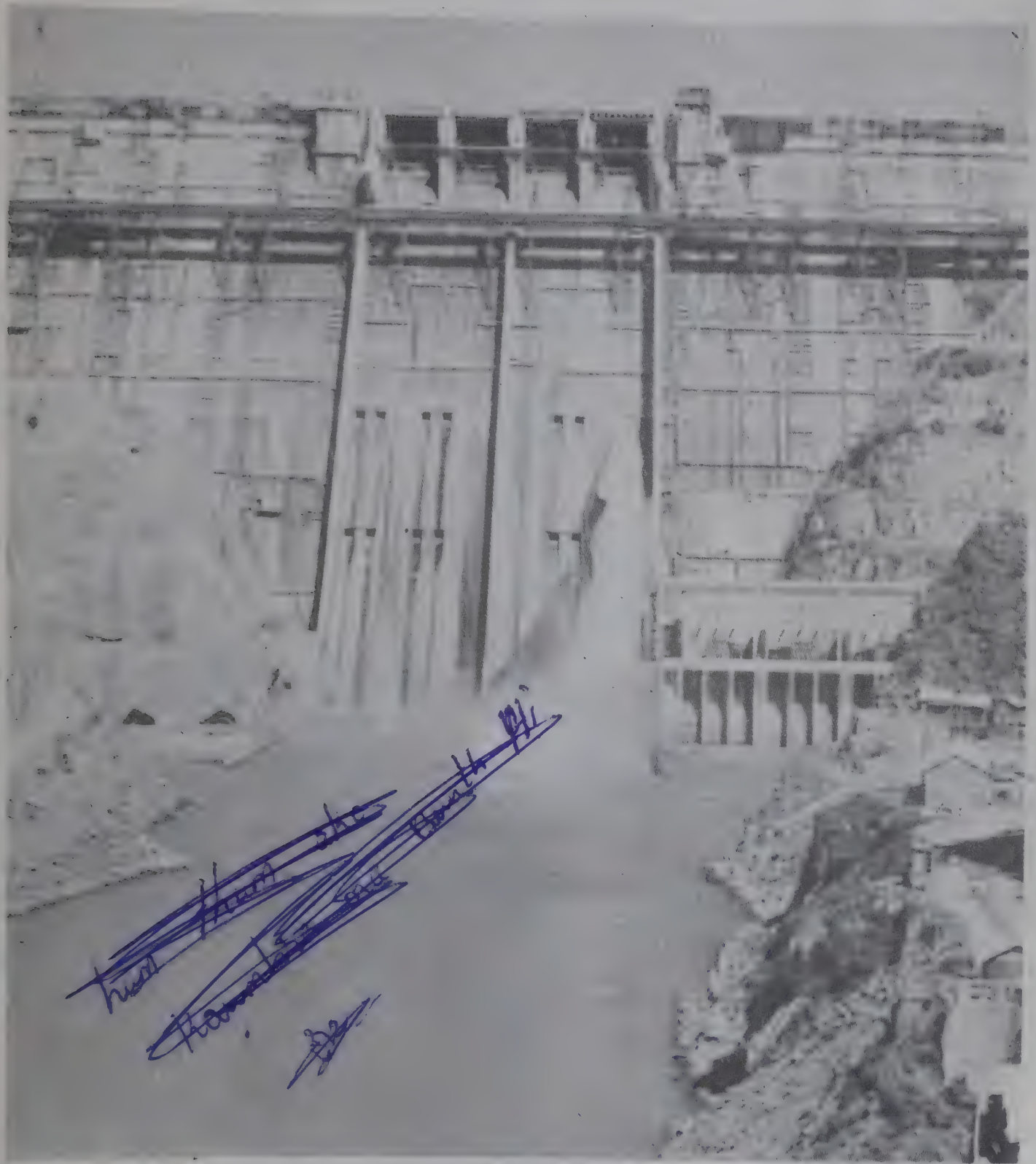
Apart from canals, tube-wells tap supplies of water that lie under the surface of the earth. Sprinkler systems help to scatter the water over large areas; and tanks and small artificial reservoirs store this precious liquid. With a regular supply of water, farmers have been able to set themselves ambitious targets and, what is more, are able to achieve them. Truly, it has been a green revolution.

A major source of water in north India is the Ganga. However this great river was being polluted by industries and sewage. In 1985, the government set up the Central Ganga Authority to clean the river. This project is now underway.

One of the reasons for the success of the agricultural revolution has been better education. Agricultural colleges have been established in practically every part of the country. At these institutions, young people are trained in scientific methods of farming, dairy farming, horticulture, and nutrition among

Spraying pesticides from the air





Bhakra Dam



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other things. Research facilities are available and new and improved technology is constantly being developed.

Agricultural universities include extension work in their curriculum during which they offer information and help to farmers in neighbouring villages thus raising the general level of expertise in rural areas.

Knowledge and experienced help in the veterinary sciences is also very important. In response to a growing demand for more educational facilities in this science, several new training institutions have been established. The government also has a number of institutions where scientists are breeding animals that will yield larger amounts of vital foods such as milk, eggs and meat. Tied in with this is the development of fisheries.

Operation Flood has improved the system of milk collection and supply. And now, edible oils are being produced in larger quantities and from a wider range of plants than ever before.

Apart from food crops, India's crops include cotton, jute, tobacco, sugarcane and rubber. Improved methods of cultivation have resulted in a greater output

Medical check-up of animals



of cotton. Besides this, there has been an increase in the manufacture of man-made fibres and cotton is being blended with synthetic fabrics to produce a whole new range of textiles. India's modern textile industry is part of her inheritance of making beautiful cloth which is in demand all over the world.

Then there are Indian silks in a bewildering range which, because of better technology, are now produced not only faster but under quality control conditions. Jute is another important crop. Indian scientists are experimenting with methods to improve its processing and increase the variety of products that can be made from it. Experiments to augment the productivity of rubber plants are also being carried out.



A hand loom

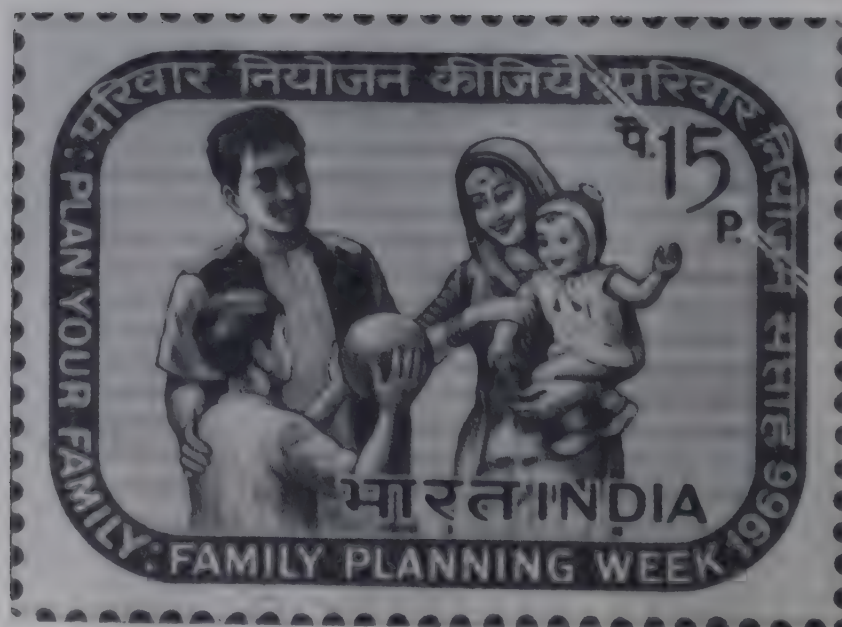
Sugar is one of India's most important products. Extracting and refining it from cane is a laborious business which yields several waste materials. Scientists have not only improved upon the process of making sugar, they are engaged in finding uses for the waste as well. Already, the waste materials are being used to make fertilizers, bio-gas and lactic acid.

As important as research and development is the classification of resources. The Botanical Survey classifies plants and studies their ecological, pharmacological, and chemical potential. Other survey departments are involved in studying and classifying the land, animals, minerals, mines, and the social habits of people. Their findings add to the sum of knowledge in all these spheres.

The indiscriminate chopping of trees, particularly in the Himalayas, has serious consequences. Efforts at replanting tracts of denuded forest are being supplemented by widespread propaganda on the disastrous effects of such unthinking activity on the environment.

Medicine has always been a subject of special interest to Indian scientists. Continuing this tradition, modern institutes are working on finding cures for chronic and infectious diseases, and the means of preventing them. Complementing medical research are several intensive study and training programmes in nutrition education. Unless improved food and an awareness of hygiene go hand in hand with better medical facilities there can be little improvement in health. In fact, the Constitution of India reflects this awareness: "The State shall regard the raising of the level of nutrition and standard of its people and the improving of public health as among its primary duties."

Studies are being made of specific diseases and ways to prevent them.





In our laboratories



Smallpox has been eradicated and no case has been reported since 1975. Research is now aimed at the control of malaria, leprosy, tuberculosis, cholera, filariasis and trachoma. There is particular emphasis on family planning in an effort to curb the growth of population, since an excessive increase in the number of people such as we have in India today, is at the root of most of the problems the country faces. Smaller families mean better food, clothing, shelter and education for each member and, at the national level, fewer people mean better facilities and more prosperity for everyone. Scientists are experimenting with new methods of family planning, and health workers and doctors are combing the countryside, explaining the need for small families. The pace of change is perhaps not rapid enough but a beginning has been made.

Thus it is evident that the importance of scientific study is, as it always has been, recognized and a great deal is being done to aid scholars and scientists by providing adequate facilities, funds and encouragement.

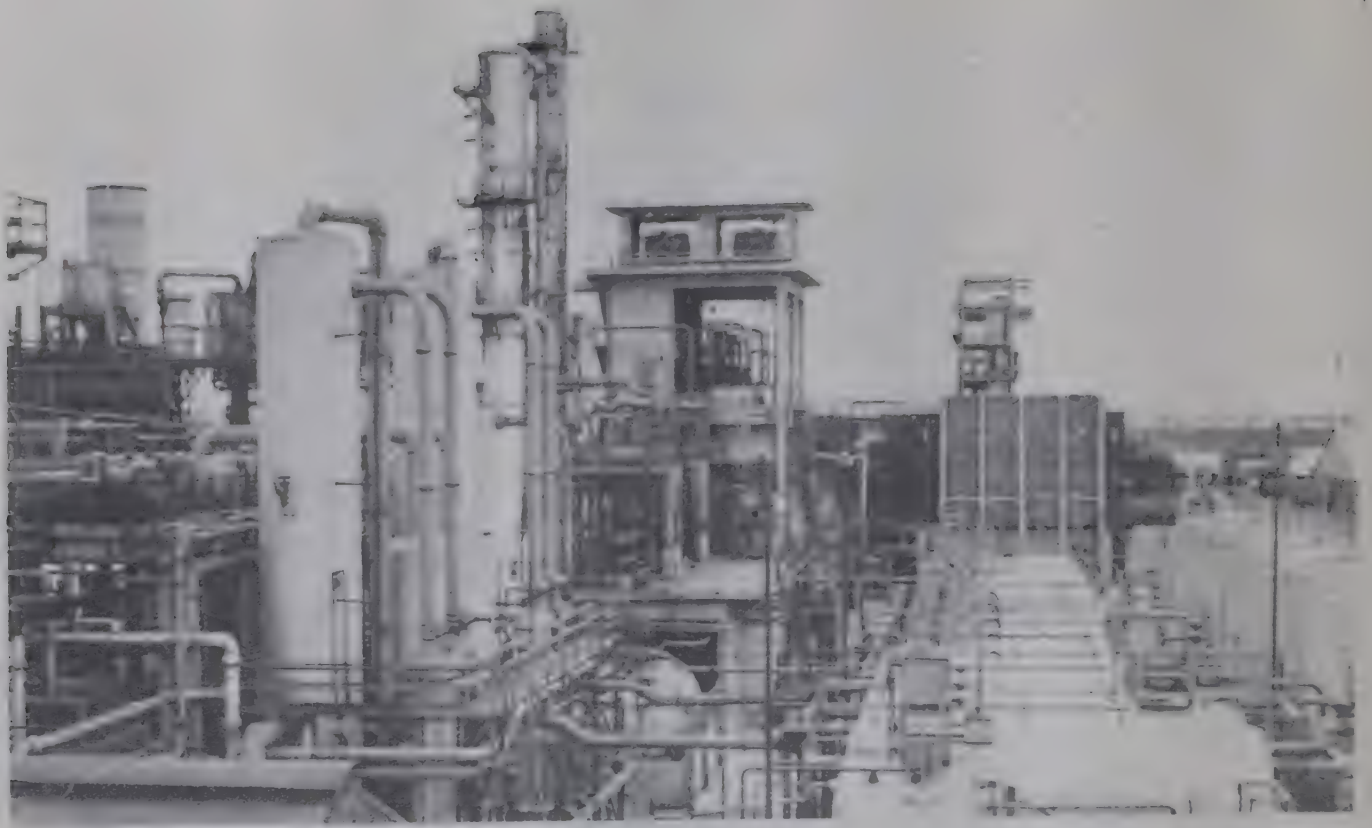
Today, survey and research work in industry has increased enormously.

Microwave tower →

Ground station for T.V. with chicken-mesh antenna



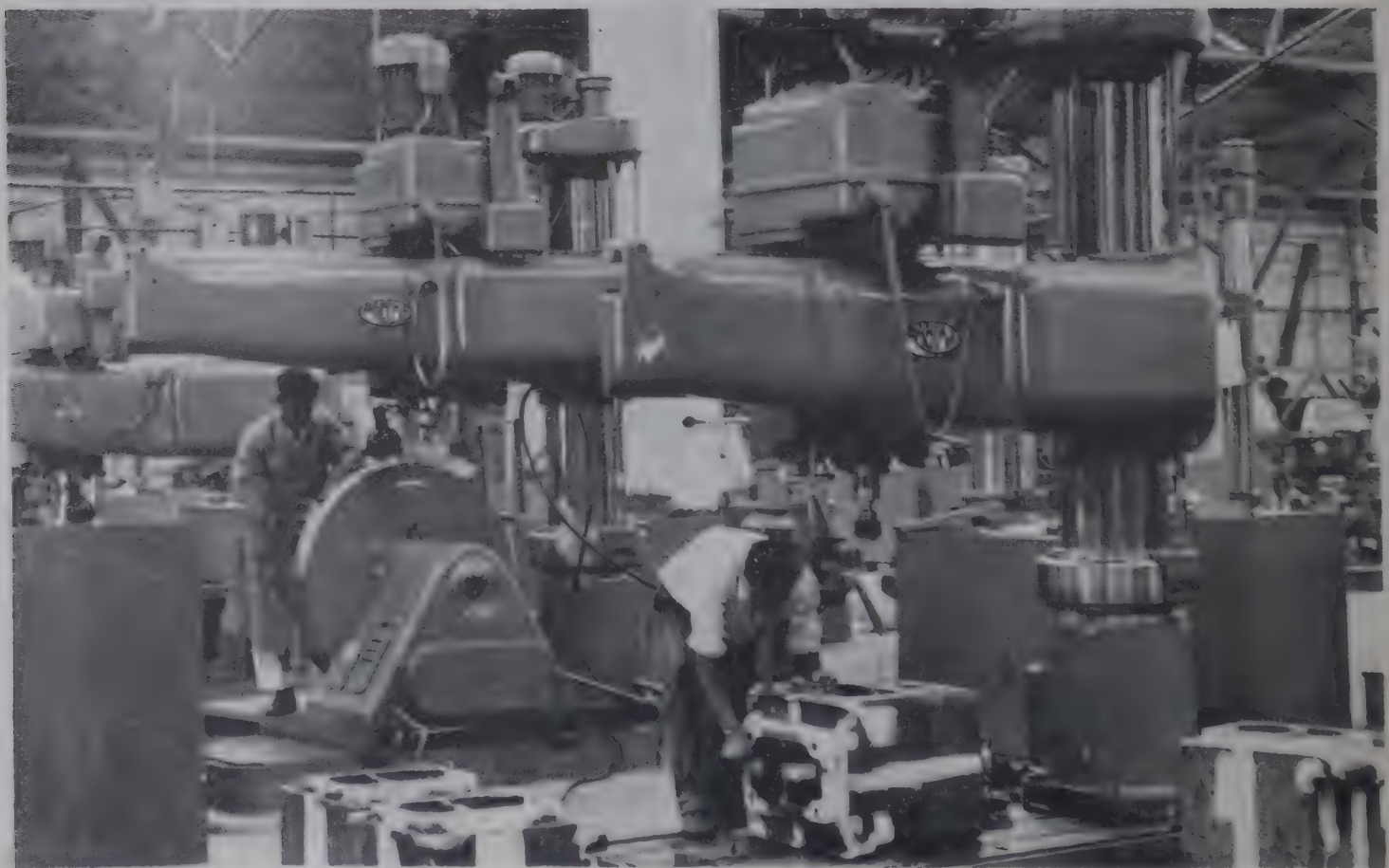




Oil refinery

Although much of the finance for it comes from the government, there has recently been a spurt in privately funded research and development work.

Heavy machine tool factory



Steel plant →



For one, a great deal of ingenuity and thought have gone into producing better scientific instruments. In the eighteenth century, Sawai Jai Singh rejected the brass astronomical instruments used in Europe in favour of his own devices built in masonry, which proved to be more accurate. His spirit lives on in the manufacture of a variety of sensitive, sophisticated instruments. Indian scientists have improved upon appliances used in optics and in medicine, such as the cardoscope and the pace-maker. Indian-made instruments also include those used in civil engineering, the earth sciences, aeronautics and meteorology. Apart from these, India produces excellent machine tools which are exported to numerous countries all over the world.

The manufacture of iron and steel is largely in the hands of the government. There are six integrated steel plants in the country. To supplement their production, there are several mini steel plants which have small or medium-sized furnaces, and which function by using scrap as raw material. India also produces good quality stainless steel and new techniques have been developed to make the processing of iron and steel more efficient and cheaper.

In the years before independence, India, like many other colonies, imported practically all the medicines it needed and a large amount of chemicals as well. Today, Indian companies make penicillin, streptomycin, tetracycline, vitamins and all manner of formulations of these and other drugs. Chemicals are also being produced here. Research in chemical sciences has resulted in several new processes and in a substantial growth of Indian know-how. Much of this is too technical to be easily explained, but some of the successes are the development of D.D.T. that disperses in water, and the discovery of uses for waste products. The liquid from cashewnut shells is being made into special surface coatings which are anti-corrosive and can be used for paints and lacquers for canned food. Waste from the sisal plant can be turned into hard wax and waste from sugar produces lactose. The growth in new processes extends to industries such as potteries, ceramics, glass and carbon products.

Of the boys and girls who enter college each year, a large number study to become engineers. India sets high standards in engineering for the most promising students through its five premier Institutes of Technology and a host of other engineering colleges. The graduates of these establishments enrich the quality of India's technological life. Many of them, however, have chosen to settle in other countries where they have made, and continue to make, a valuable contribution.

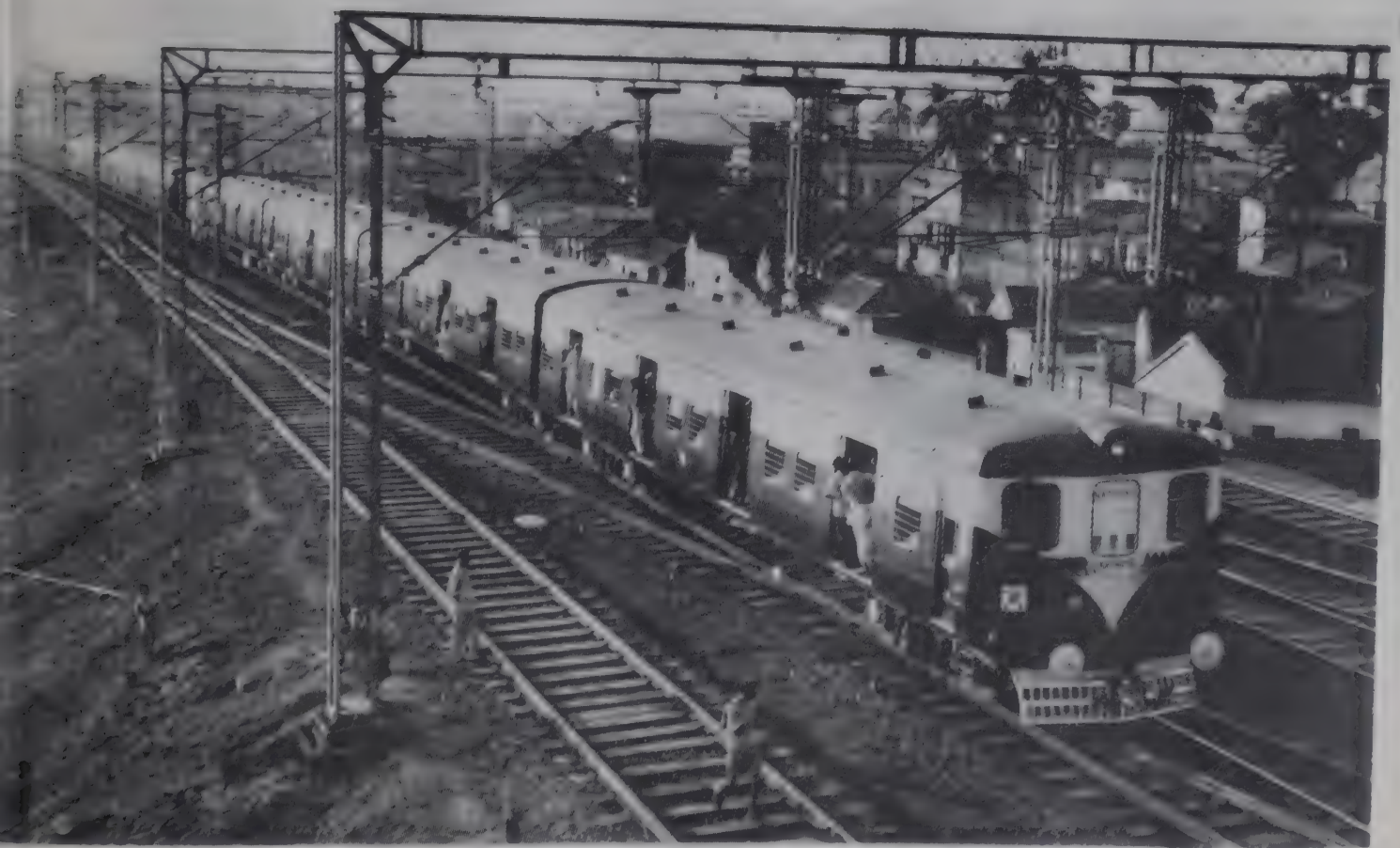
The newest kinds of machines being produced here are, needless to say, computers. These are made by the Electronics Corporation of India, and by a few private companies. The Electronics Corporation has set up over 184

computer systems and is engaged in developing computers which will use Indian languages. Regional computer centres have been established in Calcutta, Chandigarh, Pune and Kanpur. More and more private companies are using computers in their daily work and, a growing number of young people are studying computer science and technology.

Other industries are also in the process of expansion. Cable and wire-making machines have been developed to produce cables of such good quality that they are in demand all over the world. Filament winding machines for fibreglass, hydraulic dynamometers, fatigue testing machines for various products, tractors and mopeds are some of the products that Indian engineers have come up with recently.

With the expansion of industry and production, there has been an increasing need for men and women who are trained in the methods of management. To train graduates in executive and managerial skills, institutes for management studies have been established at Ahmedabad, Calcutta and Bangalore. Several universities and other institutions have followed suit and today, an

An electric train



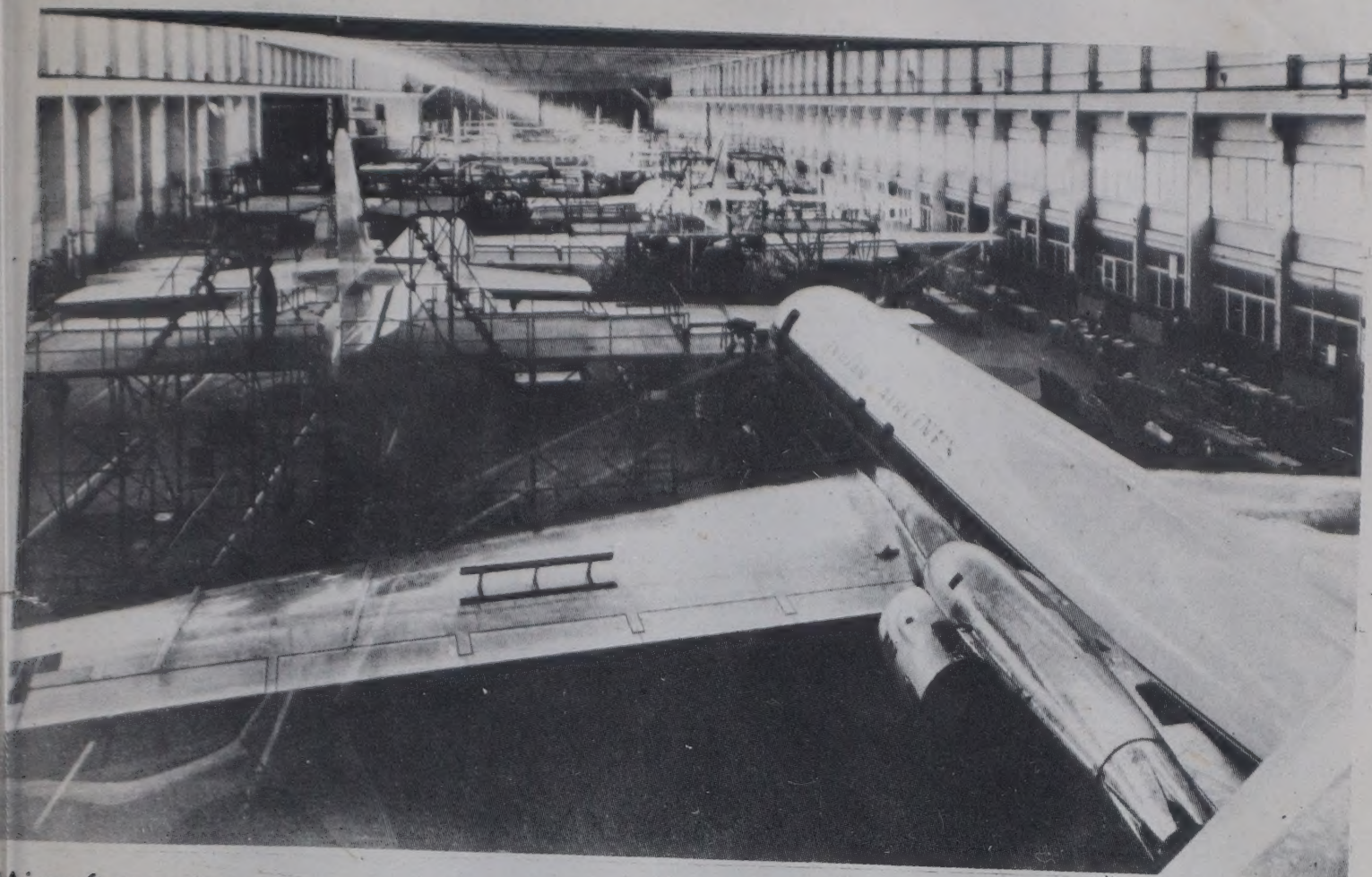
ambitious young person has a choice of full-time or part-time courses on management in most major cities.

Perhaps the best yardstick of the growth of industry in India is the fact that the market is flooded with a vast variety of locally made consumer goods. Televisions and toothpastes, toasters and dehydrated foods, cotton and synthetic textiles, paper, cutlery, vehicles, soaps, cosmetics . . . the list is endless. Less than 20 years ago, Indians looked to the West when they wished to buy electrical gadgets, cosmetics and synthetic clothes. Today, India not only makes enough to supply its own market but has a surplus for export to other countries. This highly visible change in consumer goods is reflected in every industry. The conclusion is obvious. There has been a boom in industry since 1947, largely as a result of locally developed technology and science.

A good transport system is the lifeline of commerce and industry. In India, the foundation for such a network was laid by the British. Miles and miles of railway track were laid, penetrating jungles and remote valleys, reaching isolated communities in every corner of the subcontinent. For many years the railways were the major means of transport for people and goods. The fact that the British built the railways for their own needs cannot detract from the benefits it bestowed upon the country. Today it is the largest system in Asia and one of the finest in the world. The railways are India's biggest public undertaking. Both passenger and goods traffic have more than doubled since 1951. And, so have the wagons and coaches that carry this traffic. The coaches and locomotives that draw them, are all manufactured at three locomotive works, at Chittaranjan, Varanasi, and Perambur. The factory at Chittaranjan was making steam locomotives until 1972, when it changed over to manufacturing electric and diesel engines. More than 80 per cent of the materials used to produce these locomotives are made in India. The works at Varanasi makes diesel locomotives and the factory at Perambur turns out coaches. A new coach factory was set up at Kapurthala in 1988.

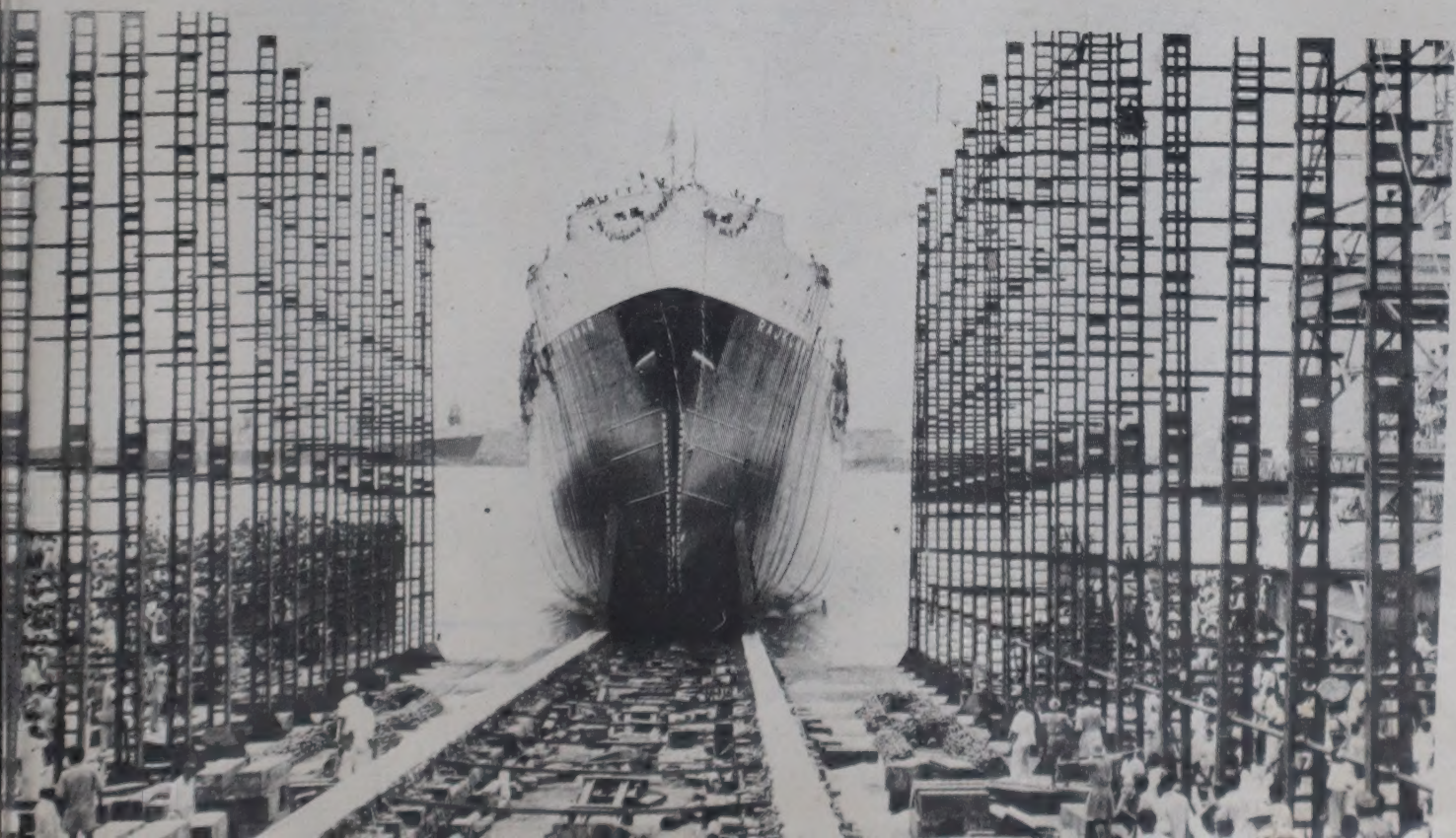
In recent years, roads have begun to carry a larger share of goods and passenger traffic. In a country as large as India, roads provide an important link between cities, towns, villages and hamlets and, before the railways came it was only by road that one could travel from one part of the country to another. In medieval times, Sher Shah built a highway that cut diagonally across north India. The Grand Trunk Road, as this highway was called, is now one of India's national highways and has been renamed Sher Shah Suri Marg in memory of the man who laid the basis for it.

Some Indian border roads traverse extremely difficult terrain, crossing mountains and Himalayan torrents, winding through barren valleys and high



Aircraft manufacture

Shipbuilding



rocky passes. A particular achievement has been the construction of the world's highest road from Manali in Himachal Pradesh to Leh in Ladakh. The average height of this road is 1,400 feet.

Most of the vehicles that travel on Indian roads have been built in this country. India makes cars, jeeps, trucks, buses, motorcycles, scooters, mopeds, bicycles and, of course, bullock-carts! India exports its motorcyles, scooters and bicycles to a number of countries. The Indian bullock-cart is one of the oldest means of transport in the world, and it continues to be useful. Bullock-carts have been improved in design and efficiency. Many now have tyres instead of wooden wheels, and the yoke and cart themselves are changing for the better.

India also builds ships and aeroplanes, tanks and tractors. India's four major shipyards build ships, tugs, barges, dredgers and coastal steamers. The Hindustan Aeronautics Limited complex in Bangalore produces fighter and transport aircraft for defence, and smaller crop spraying craft for agricultural needs. It also makes helicopters. Civil airlines link the major cities by a regular air service. India has five international airports and 85 major aerodromes.

Bullock-carts and satellites, mud lamps and nuclear energy: India encompasses them all, retaining utilitarian objects from the past yet being able to adopt the newest technological knowledge. It is this spirit of adaptability and innovation that has always characterized Indian achievements and is now contributing to India's rapid development.



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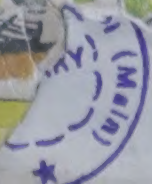
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